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NRL Report 7765
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Probability of Detecting Ships With an OTH Radar System

[Unclassified Title]

JON DAVID WILSON

Radar Analysis Staff
Radar Division

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Over-the-horizon radar
Probability of ships detection
Probability of skywave propagation
Sea clutter spectrum

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

(U) An over-the-horizon (OTH) radar uses ionospheric reflection of high-frequency radio waves to propagate to areas far beyond the normal radar horizon. Two principle probabilities are associated with an OTH radar: the probability of successfully propagating to a given region via the ionosphere and the probability of detecting a target in sea clutter, given that propagation occurred. A particular radar system was examined and tables of probabilities were generated for various ionospheric and target parameters. An example illustrates the method of combining these probabilities to obtain a composite probability of

(Continued)

20. Abstract (Continued)

detection. The probability of propagating was calculated by a computer program that used radar parameters, the ionospheric parameters, the geographical location, and the time of day and year as inputs. The probability of detection involved a computer implementation of the radar range equation.

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PROBABILITY OF DETECTING SHIPS WITH AN OTH RADAR SYSTEM
[Unclassified Title]

INTRODUCTION

(U) This report is based on one phase of a study being conducted at the Naval Research Laboratory (NRL) [1-6] to compare the cost and effectiveness of three different radar systems used for ocean surveillance. The three candidate systems are an airborne radar, a satellite-borne radar, and a ground-based over-the-horizon (OTH) radar. For this report, the probability of detection of one particular OTH system has been calculated. The methods used, however, can be applied to any OTH system.

PROBABILITY OF PROPAGATION

(S) The ability of a radar system to propagate to a given range at a given time of the year was found by using RADARC, which is a computer program written by the Institute of Telecommunication Sciences to meet OTH radar analysis requirements as specified by NRL [7]. This program calculates the median clutter-to-noise ratio (C/N) for an OTH radar. The size of the backscatter area is calculated from virtual height ionograms using geometrical optics techniques. The noise considered includes atmospheric, galactic, and man-made sources. Atmospheric and ionospheric losses are included and the C/N is calculated from the radar range equation. This calculation was performed for sporadic E, E, F_1, and F_2 layer propagation modes. If the clutter return and signal return are assumed to be affected by the ionosphere in a similar manner, propagation is defined by requiring the signal return from 1000-m^2 target to be large enough against noise to yield a probability of detection P_D equal to 0.9 and a probability of false alarm P_{fa} equal to 10^{-6} for a Type 1 OTH FM-CW radar system [6]. This system has the following parameters:

100-kw average power
0.1-s frequency sweep (prf = 10 per second)
20-μs compressed pulse length
2.5-km horizontal aperture, receive ($\approx 0.25° - 1°$), transmit ($\approx 6° - 10°$).

We now calculate the C/N required for propagation.

(S) First, in order to obtain a $P_{\mathrm{fa}} = 10^{-6}$ and a $P_D = 0.9$, the integrated signal-to-noise ration (S/N) should be 13 dB. The FM-CW radar system is assumed to have 10 frequency sweeps per second, a coherent integration time of 25 s, and a total integration time of 250 s. From Rubin and Difranco [8], the noncoherent integration gain for 10 noncoherent pulses is found to be 7 dB. With coherent integration, the noise spectrum extends from -5 to +5 Hz and is separated into 250 doppler bins of width 0.04 Hz. Thus,

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Note: Manuscript submitted May 14, 1974.

the required S/N per doppler bin is 6 dB, (13 dB - 7 dB), and the S/N in a cycle bandwidth is -8 dB, or [6 dB + 10 log (0.04)]. Since the signal and clutter are assumed to propagate in a similar manner, the signal-to-clutter ratio (S/C) is given by

$$\frac{S}{C} = \frac{\sigma_T}{\frac{\sigma_0 \theta_B R c \tau}{2}} = -33 \text{ dB} \tag{1}$$

where

σ_T = target cross section (30 dBsm),

σ_0 = relative sea clutter cross section (-17 dB)

θ_B = antenna beamwidth (1°)

R = radar range, 1000 n.mi.

c = speed of light

τ = effective pulse width, 20 μs.

Now, the required C/N for propagation is calculated from

$$\frac{C}{N} = \frac{\frac{S}{N}}{\frac{S}{C}} = 25 \text{ dB.*} \tag{2}$$

Even though the madre antenna pattern is wired into RADARC, the received clutter and noise powers are independent of the receive antenna beamwidth,† and consequently, RADARC can be used to calculate propagation for the FM-CW radar system. The only alterations made to the program were to eliminate printed output and to add the punched output used in calculating the propagation statistics.

(S) The ability to propagate was found for four months, (January, April, July, or October), two times (day or night), and three sunspot numbers (20, 45, or 75, which are the 25th, 50th, and 75th percentiles). The radar is situated in Maine (latitude 45° N, longitude 67° W). For each of the 24 conditions, the radar model RADARC was used to calculate the C/N every 2 hr for three azimuth angles (14°, 59°, and 104°), spanning a 90° sector. For each set of parameters, one-bounce propagation via four layers (sporadic E, E, F_1, F_2) was considered and the maximum C/N chosen. The number of occasions out of 18 (6 times, 2 hr apart, and 3 azimuths) that the C/N exceeded 25 dB is given in Tables 1-24. We can interpret these numbers divided by 18 as a probability of propagation. If

*Specifically, a C/N of 25 dB is equivalent to our defined propagation at 1000 n.mi. for a 30-dB target and the particular frequency that yields a 1° beamwidth. For other ranges, targets, and frequencies, 25 dB was still used since C/N varies rapidly with range and hence a change in the threshold (25 dB) would have little effect on the region of propagation.

†When the transmit beamwidth is larger than the receive beamwidth, the receive array is sampling an extended source. When the beamwidth narrows, the clutter (or atmospheric noise) patch narrows, but the gain of the array increases.

(U) Table 1
Number of successful propagations out of 18 possible opportunities, in January, in nighttime with SNS=20 as a function of range and frequency

MONTH = JAN NIGHT SUN SPOT = 20

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	16	13	9	0	0	0	0	0
1000	18	16	13	10	7	3	0	0
1500	17	2	0	0	0	0	0	0
2000	15	5	0	0	0	0	0	0

(U) Table 2
Number of successful propagations out of 18 possible opportunities, in January, in daytime with SSN=20 as a function of range and frequency

MONTH = JAN DAY SUN SPOT = 20

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	18	18	9	0	0	0	0	0
1000	16	18	18	14	4	0	0	0
1500	3	9	13	12	8	3	0	0
2000	2	4	4	5	5	5	0	0

(U) Table 3
Number of successful propagations out of 18 possible opportunities, in April, in nighttime with SSN=20 as a function of range and frequency

MONTH = APR NIGHT SUN SPOT = 20

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	18	12	6	0	0	0	0	0
1000	18	16	12	8	3	0	0	0
1500	15	8	4	0	0	0	0	0
2000	12	10	5	1	0	0	0	0

(U) Table 4
Number of successful propagations out of 18 possible opportunities, in April, in daytime with SSN=20 as a function of range and frequency

MONTH = APR DAY SUN SPOT = 20

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	18	18	4	0	0	0	0	0
1000	8	16	15	11	2	0	0	0
1500	0	4	9	10	1	0	0	0
2000	0	2	5	7	5	0	0	0

(U) Table 5
Number of successful propagations out of 18 possible opportunities, in July, in nighttime with SSN=20 as a function of range and frequency

MONTH = JUL NIGHT SUN SPOT = 20

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	18	18	15	4	3	0	0	0
1000	18	18	18	17	15	8	5	2
1500	13	11	6	1	0	0	0	0
2000	7	11	6	3	0	0	0	0

(U) Table 6
Number of successful propagations out of 18 possible opportunities, in July, in daytime with SSN=20 as a function of range and frequency

MONTH = JUL DAY SUN SPOT = 20

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	17	16	16	2	1	0	0	0
1000	5	13	17	10	13	13	6	1
1500	0	3	9	8	0	0	0	0
2000	0	1	2	3	3	0	0	0

(U) Table 7
Number of successful propagations out of 18 possible opportunities, in October, in nighttime with SSN=20 as a function of range and frequency

MONTH = OCT NIGHT SUN SPOT = 20

	FREQUENCY (MHZ)							
RANGE (NM)	6	9	12	15	18	21	24	27
500	18	15	9	2	0	0	0	0
1000	18	18	15	12	8	4	2	0
1500	16	7	1	0	0	0	0	0
2000	14	10	1	0	0	0	0	0

(U) Table 8
Number of successful propagations out of 18 possible opportunities, in October, in daytime with SSN=20 as a function of range and frequency

MONTH = OCT DAY SUN SPOT = 20

	FREQUENCY (MHZ)							
RANGE (NM)	6	9	12	15	18	21	24	27
500	18	18	9	0	0	0	0	0
1000	11	18	18	17	6	2	0	0
1500	3	7	14	15	8	2	0	0
2000	0	4	6	9	13	7	0	0

(U) Table 9
Number of successful propagations out of 18 possible opportunities, in January, in nighttime with SSN=45 as a function of range and frequency

MONTH = JAN NIGHT SUN SPOT = 45

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	16	13	8	0	0	0	0	0
1000	18	16	13	9	5	3	0	0
1500	17	5	0	0	0	0	0	0
2000	15	11	0	0	0	0	0	0

(U) Table 10
Number of successful propagations out of 18 possible opportunities, in January, in daytime with SSN=45 as a function of range and frequency

MONTH = JAN DAY SUN SPOT = 45

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	18	18	13	0	0	0	0	0
1000	15	18	18	16	7	0	0	0
1500	3	8	15	14	11	7	2	0
2000	1	6	9	5	8	7	5	0

(U) Table 11
Number of successful propagations out of 18 possible opportunities, in April, in nighttime with SSN=45 as a function of range and frequency

MONTH = APR NIGHT SUN SPOT = 45

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	18	13	5	0	0	0	0	0
1000	18	17	14	8	3	0	0	0
1500	14	14	5	2	0	0	0	0
2000	12	13	8	4	0	0	0	0

(U) Table 12
Number of successful propagations out of 18 possible opportunities, in April, in daytime with SSN=45 as a function of range and frequency

MONTH = APR DAY SUN SPOT = 45

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	17	18	3	0	0	0	0	0
1000	5	13	18	9	2	0	0	0
1500	0	3	8	12	7	0	0	0
2000	0	2	5	6	8	4	0	0

(U) Table 13
Number of successful propagations out of 18 possible opportunities, in July, in nighttime with SSN=45 as a function of range and frequency

MONTH = JUL NIGHT SUN SPOT = 45

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	18	18	15	3	2	0	0	0
1000	18	18	18	16	14	8	5	2
1500	12	15	7	3	0	0	0	0
2000	6	14	6	6	1	0	0	0

(U) Table 14
Number of successful propagations out of 18 possible opportunities, in July, in daytime with SSN=45 as a function of range and frequency

MONTH = JUL DAY SUN SPOT = 45

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	16	18	15	2	1	0	0	0
1000	5	11	17	8	13	13	6	1
1500	0	2	6	13	1	0	0	0
2000	0	0	2	2	8	0	0	0

(U) Table 15
Number of successful propagations out of 18 possible opportunities, in October, in nighttime with SSN=45 as a function of range and frequency

MONTH = OCT NIGHT SUN SPOT = 45

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	18	15	9	0	0	0	0	0
1000	18	18	15	12	8	4	1	0
1500	15	12	3	0	0	0	0	0
2000	14	14	5	1	0	0	0	0

(U) Table 16
Number of successful propagations out of 18 possible opportunities, in October, in daytime with SSN=45 as a function of range and frequency

MONTH = OCT DAY SUN SPOT = 45

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	18	18	16	0	0	0	0	0
1000	10	18	18	17	13	1	0	0
1500	3	6	12	18	14	8	2	0
2000	0	2	5	9	13	13	8	1

(U) Table 17
Number of successful propagations out of 18 possible opportunities, in January, in nighttime with SSN=75 as a function of range and frequency

MONTH = JAN NIGHT SUN SPOT = 75

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	16	13	8	0	0	0	0	0
1000	18	15	13	9	4	1	0	0
1500	18	10	1	0	0	0	0	0
2000	15	14	2	0	0	0	0	0

(U) Table 18
Number of successful propagations out of 18 possible opportunities, in January, in daytime with SSN=75 as a function of range and frequency

MONTH = JAN DAY SUN SPOT = 75

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	18	18	12	2	0	0	0	0
1000	2	18	18	16	9	4	0	0
1500	3	7	13	16	13	10	5	2
2000	2	4	7	12	10	10	7	5

(U) Table 19
Number of successful propagations out of 18 possible opportunities, in April, in nighttime with SSN=75 as a function of range and frequency

MONTH = APR NIGHT SUN SPOT = 75

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	18	14	5	0	0	0	0	0
1000	18	18	14	8	3	0	0	0
1500	15	18	11	4	0	0	0	0
2000	11	15	14	6	2	0	0	0

(U) Table 20
Number of successful propagations out of 18 possible opportunities, in April, in daytime with SSN=75 as a function of range and frequency

MONTH = APR DAY SUN SPOT = 75

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	16	18	7	0	0	0	0	0
1000	5	14	18	14	4	0	0	0
1500	0	3	7	12	11	5	0	0
2000	0	2	4	7	11	10	3	0

(U) Table 21
Number of successful propagations out of 18 possible opportunities, in July, in nighttime with SSN=75 as a function of range and frequency

MONTH = JUL NIGHT SUN SPOT = 75

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	18	18	14	3	1	0	0	0
1000	18	18	18	15	14	7	5	1
1500	12	15	10	6	1	0	0	0
2000	6	14	13	7	4	0	0	0

(U) Table 22
Number of successful propagations out of 18 possible opportunities, in July, in daytime with SSN=75 as a function of range and frequency

MONTH = JUL DAY SUN SPOT = 75

RANGE (NM)	FREQUENCY (MHZ) 6	9	12	15	18	21	24	27
500	14	18	17	1	1	0	0	0
1000	2	10	18	9	17	16	5	1
1500	0	2	5	13	4	0	0	0
2000	0	0	2	3	7	1	0	0

(U) Table 23
Number of successful propagations out of 18 possible opportunities, in October, in nighttime with SSN=75 as a function of range and frequency

MONTH = OCT NIGHT SUN SPOT = 75

RANGE (NM)	6	9	12	15	18	21	24	27
	FREQUENCY (MHZ)							
500	18	15	9	0	0	0	0	0
1000	18	18	15	12	7	3	0	0
1500	15	15	7	1	0	0	0	0
2000	13	17	12	3	0	0	0	0

(U) Table 24
Number of successful propagations out of 18 possible opportunities, in October, in daytime with SSN=75 as a function of range and frequency

MONTH = OCT DAY SUN SPOT = 75

RANGE (NM)	6	9	12	15	18	21	24	27
	FREQUENCY (MHZ)							
500	18	18	17	4	0	0	0	0
1000	9	18	18	18	16	7	0	0
1500	2	5	11	18	15	14	8	3
2000	0	3	6	9	16	13	13	8

the tables are compared, the following general conclusions can be reached about propagation when using the optimal frequency for a given range:

- Better at night than during the day
- Better in winter than in summer
- For the sunspot numbers considered, better for the higher sunspot numbers
- Propagation is very close to 100% for the shorter ranges.

The following conclusions can be reached about frequency preferences:

- Higher frequencies during daytime
- Higher frequencies during summertime
- Higher frequencies for higher sunspot numbers
- Higher frequencies for longer ranges.

PROBABILITY OF DETECTION

(U) In the previous section successful propagation was defined in terms of detection of targets against noise. Consequently, in this section we will consider only the detection of targets in sea clutter.

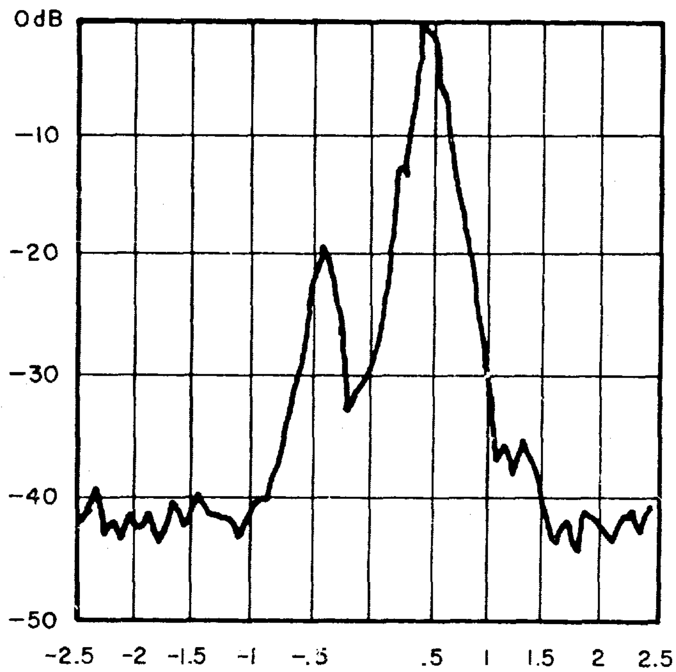
(C) The basic assumption is that the target return (small region) and the clutter return (extended region) will be affected in the same way by passage through the ionosphere. This allows us to calculate the *S/C* at the input to the processor from the target and clutter radar cross sections. The principal signal enhancement is from doppler processing with an additional noncoherent integration of the doppler cells.

(S) The *S/C* was calculated from Eq. (1) with three different target cross sections, 1000-m^2 and 3000-m^2 destroyers and a 50,000-m^2 aircraft carrier; and four ranges, 500, 1000, 1500, and 2000 n.mi, for each target type. The doppler processing gain was calculated for a set of radial velocities from -30 to +30 knots and a range of operating frequencies from 5 to 30 MHz. We assumed the target to be in one doppler cell and a 2-dB loss for processing and target doppler spread. The clutter level in a given doppler cell was obtained by normalizing a sample clutter spectrum. Two sample clutter spectra were derived from a working paper by Dr. James R. Barnum of Standford Research Institute [9]. One asymmetrical spectrum represents the type of clutter spectrum observed with approaching (or receding) winds. The other spectrum is symmetric and is typical of the spectra observed in crosswind conditions.

(U) One observed clutter spectrum was used to generate both spectra. This particular spectrum was chosen on the basis of its clean appearance, but all of the candidate spectra from Ref. 9 have certain features in common, such as the Bragg scatter peaks, the lowered level of clutter between these peaks, and the even lower level of clutter in the doppler cells outside of the peak. The symmetrical (crosswind) clutter spectrum was obtained by averaging the clutter cells symmetrically placed about the carrier frequency. This process yielded a spectrum that appears to be a valid approximation to observed

crosswind spectra. This approximation was used because there was always at least a small asymmetry in the levels of the approaching and receding Bragg scattering lines of the observed spectra (an asymmetry would favor either the approaching or receding targets).

(U) The asymmetrical clutter spectrum is shown in Fig. 1. This spectrum was extended to ±5 Hz at a -42 dB level. The sea clutter, of course, does not have a plateau at some particular level below the Bragg line peak but has been measured on the Madre radar (with a 70-dB dynamic range) to drop off to at least 65 to 70 dB below the peak at ±5 Hz. The -42 dB plateau seems to be a feature of the radar on which the spectrum was measured. This would make little difference in our results: If the target is not in a Bragg line peak, it is detected. The two large spikes correspond to the Bragg scatter of ocean waves. The relative amplitude of the two spikes is a function of the angle of the ocean wavefront to the radar wavefront and hence depends on local wind direction [10]. The doppler offset of these spikes from the carrier frequency depends on the carrier frequency. The particular spectrum shown as measured at 20 MHz. At other radar frequencies, the spectral line spacing expands and contracts with the square root of the carrier frequency [11].



(U) Fig. 1—Typical clutter doppler spectrum

(S) The doppler cell in which the target appears is calculated from the radial speed V_r and operating wavelength λ by

$$\text{Doppler cell} = \frac{2V_r}{\lambda(0.04)}. \quad (3)$$

(S) The clutter energy in that cell is calculated from the normalized clutter spectrum (shifted by the operating frequency). The S/C obtained for this radial speed and operating frequency combination is interpolated into a table of values, giving the P_d for 10 pulses [8]. For purposes of display, an array of symbols indicating the probability level for each combination of speed and frequency is printed. The P_d results for the approaching wind clutter spectrum are given in Figs. 2-13 and the crosswind results are given in Figs. 14-25. In the figures, an integer N indicates that P_d is between $0.1(N)$ and $0.1(N + 1)$ and a blank indicates that P_d is less than 0.1. The following observations can be made.

- Smaller targets can be detected only at the higher radial velocities, whereas the largest target can be detected in all doppler cells except those occupied by the Bragg scatter lines.

- Better detection performance is observed in the nonsymmetrical spectrum. This can be attributed (a) to the concentration of clutter energy in the larger Bragg scatter peak where detection is impossible in any case, and (b) to the consequent reduction of clutter energy in the remaining doppler cells.

- Targets can be detected in more of the doppler cells at higher frequencies. This is because the target doppler is proportional to frequency, whereas the clutter spectrum expands as the square root of the frequency. Thus, as the frequency is raised targets obscured by the clutter peak move into doppler cells of lower clutter.

(U) This last point may be the result of using one clutter spectrum taken at one carrier frequency and expanded and contracted for other frequencies. The clutter spectrum is affected by both sea state and frequency, but we did not have available sufficient data to make quantitative adjustment to the assumed spectrum. The doppler level in the cells away from the Bragg lines increases with the carrier frequency, and our sample spectrum was measured at a relatively high frequency. This means that at low frequencies the clutter levels used in our calculation are too high, but again, it would not affect our results; if a target is not in a Bragg line peak, it is detected.

(U) The preceding detection curves (Figs. 2-25) were based on the assumption that σ_0 = -17 dB. However, since there is some controversy over the value of σ_0 (Barnum has data that indicate σ_0 = -23 dB [12]), additional detection curves are generated for σ_0 = -23 dB. These curves are displayed in Figs. 26-49. Obviously the only difference between the results and the previous results is an improvement of 6 dB.

RESULTS

(S) To obtain a composite P_d, we multiply the probability of propagation (from Tables 1-24) by the probability of detection given that propagation is successful (Figs. 2-49). Two examples, one for σ_0 = -17 dB the other for σ_0 = -23 dB, are shown in Figs. 50 and 51, respectively. The composite P_d for each of four ranges is plotted vs radial speed. The target has a 3000-m^2 radar cross section in April, in daytime under crosswind conditions, with a sunspot number of 45. The operating frequency for each range is the frequency that yields the best composite P_d over the largest speed range. Only closing speeds are shown because of the symmetrical clutter spectrum. From these curves it appears that it is very difficult to detect a 3000-m^2 target at radial speeds below 15 knots if σ_0 = -17 dB and

RADIAL SPEED (KNOTS)

	-30 -25 -20 -15 -10	-5 0 5	10 15 20 25 30
5	999999999961	13321	3
6	99999999999982	25421	1599
7	999999999999994	137542	279999
8	99999999999999961	158753	38999999
9	999999999999999971	29865	599999999
10	9999999999999999982	379761	16999999999
11	9999999999999999993	1489871	179999999999
12	99999999999999999994	599982	2899999999999
13	99999999999999999995	299982	38999999999999
14	999999999999999999991	399993	49999999999999
15	999999999999999999996	499994	599999999999999
16	9999999999999999999971	48999	1999999999999999
17	9999999999999999999992	59999	6999999999999999
18	9999999999999999999998	199991	17999999999999999
19	9999999999999999999999	199991	29999999999999999
20	99999999999999999999994	299991	89999999999999999
21	99999999999999999999994	299991	399999999999999999
22	99999999999999999999995	399992	399999999999999999
23	99999999999999999999999	389992	999999999999999999
24	999999999999999999999981	99993	4999999999999999999
25	999999999999999999999981	99993	5999999999999999999
26	999999999999999999999986	99993	15999999999999999999
27	999999999999999999999987	99994	19999999999999999999
28	999999999999999999999987	199994	19999999999999999999
29	999999999999999999999988	199995	69999999999999999999
30	9999999999999999999999892	199995	79999999999999999999

(S) Fig. 2—P_d of 1000·m^2 target at 500-n.mi. range in approaching sea clutter, $\sigma_0 = -17$ dB

RADIAL SPEED (KNOTS)

	-30 -25 -20 -15 -10	-5 0 5	10 15 20 25 30
5	9999999994		
6	9999999999961		27
7	99999999999982		4999
8	999999999999994	1	1699999
9	9999999999999995	21	29999999
10	999999999999999961	121	899999999
11	999999999999999997	1411	19999999999
12	9999999999999999982	2521	199999999999
13	9999999999999999999	3631	1699999999999
14	99999999999999999994	4742	7999999999999
15	99999999999999999995	4743	39999999999999
16	999999999999999999991	1873	389999999999999
17	999999999999999999996	2974	499999999999999
18	9999999999999999999971	2985	999999999999999
19	9999999999999999999992	3985	5999999999999999
20	9999999999999999999992	3996	19999999999999999
21	9999999999999999999998	4896	69999999999999999
22	9999999999999999999999	4897	79999999999999999
23	99999999999999999999994	1997	299999999999999999
24	99999999999999999999994	2998	299999999999999999
25	99999999999999999999995	2998	899999999999999999
26	99999999999999999999999	2999	999999999999999999
27	999999999999999999999981	3999	4999999999999999999
28	999999999999999999999981	3999	4999999999999999999
29	999999999999999999999991	3999	9999999999999999999
30	999999999999999999999986	4999	9999999999999999999

(S) Fig. 3—P_d of 1000-m^2 target at 1000-n.mi. range in approaching sea clutter, $\sigma_0 = -17$ dB

```
                               RADIAL SPEED(KNOTS)

     -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5    9999999751
 6    999999999972                                                  3
 7    9999999999983                                              1567
 8    99999999999995                                           168998
 9    9999999999999961                                        7999999
10    99999999999999972                                     489999999
11    999999999999999983           1                       5999999999
12    999999999999999994           1                      69999999999
13    9999999999999999995          2                     299999999999
14    99999999999999999951         2                    2799999999999
15    99999999999999999991        131                   8999999999999
16    99999999999999999997         42                  49999999999999
17    999999999999999999972        531                199999999999999
18    999999999999999999992        541                599999999999999
19    999999999999999999998        641               1999999999999999
20    999999999999999999999        652               6999999999999999
21    9999999999999999999994      1452              27999999999999999
22    9999999999999999999995      1463              39999999999999999
23    9999999999999999999999       563              89999999999999999
24    99999999999999999999991      574              89999999999999999
25    99999999999999999999991      574             499999999999999999
26    99999999999999999999996      674             499999999999999999
27    99999999999999999999997      685             999999999999999999
28    99999999999999999999997      785            1999999999999999999
29    99999999999999999999999      796            6999999999999999999
30    999999999999999999999992    1796            6999999999999999999
```

(S) Fig. 4—P_d of 1000-m^2 target at 1500-n.mi. range in approaching sea clutter, σ_0 = -17 dB

```
                               RADIAL SPEED(KNOTS)

     -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5    999986642
 6    99999999663                                                   1
 7    9999999999751                                               234
 8    99999999999992                                            35675
 9    999999999999993                                         4678867
10    9999999999999994                                      157897689
11    999999999999999951                                   2689987999
12    999999999999999991                                  27999999999
13    9999999999999999972                                 89999999999
14    9999999999999999992          1                    1499999999999
15    9999999999999999998          1                    5999999999999
16    99999999999999999994         1                   19999999999999
17    99999999999999999994         21                  69999999999999
18    999999999999999999991        21                 299999999999999
19    999999999999999999996        31                 799999999999999
20    999999999999999999996        32                3899999999999999
21    9999999999999999999991       12                4999999999999999
22    9999999999999999999992       131              19999999999999999
23    9999999999999999999998       231              59999999999999999
24    9999999999999999999998       241              59999999999999999
25    9999999999999999999998       241             109999999999999999
26    99999999999999999999993      352             299999999999999999
27    99999999999999999999994      352             699999999999999999
28    99999999999999999999994      452             799999999999999999
29    99999999999999999999999      462            2999999999999999999
30    99999999999999999999999      463            3999999999999999999
```

(S) Fig. 5—P_d of 1000-m^2 target at 2000-n.mi. range in approaching sea clutter, σ_0 = -17 dB

```
                          RADIAL SPEED(KNOTS)

     -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5   999999999999661         489999994                         599
 6   9999999999999982       1699999961                     1179999
 7   99999999999999994      2799999971                    38999999
 8   9999999999999999961     499999993                  4999999999
 9   99999999999999999971    599999994                159999999999
10   99999999999999999992   1699999995               1799999999999
11   999999999999999999993   299999991              27999999999999
12   9999999999999999999941  289999991              89999999999999
13   9999999999999999999991  399999992             499999999999999
14   99999999999999999999961  99999992            5999999999999999
15   99999999999999999999962  99999993           15999999999999999
16   999999999999999999999981169999994           19999999999999999
17   999999999999999999999982169999994          279999999999999999
18   999999999999999999999982179999995          299999999999999999
19   999999999999999999999995179999996          899999999999999999
20   999999999999999999999996229999996         4899999999999999999
21   999999999999999999999996439999991         4999999999999999999
22   999999999999999999999999539999991        19999999999999999999
23   999999999999999999999999549999991        19999999999999999999
24   999999999999999999999999649999991        69999999999999999999
25   999999999999999999999999849999992        69999999999999999999
26   999999999999999999999999849999992       299999999999999999999
27   999999999999999999999999959999992       299999999999999999999
28   999999999999999999999999959999993       299999999999999999999
29   999999999999999999999999969999993       899999999999999999999
30   999999999999999999999999989999993       899999999999999999999
```

(S) Fig. 6—P_d of 3000-m^2 target at 500-n.mi. range in approaching sea clutter, σ_0 = -17 dB

```
                          RADIAL SPEED(KNOTS)

     -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5   999999999995            1477643                            37
 6   999999999999971          269865                          5999
 7   9999999999999983       14899861                       1699999
 8   99999999999999994       5999982                     289999999
 9   9999999999999999951     3799993                    4999999999
10   9999999999999999996     4899994                   59999999999
11   99999999999999999972    5999995                 1699999999999
12   99999999999999999998    1999996                17999999999999
13   999999999999999999993   2799997                79999999999999
14   999999999999999999994   2799997               389999999999999
15   999999999999999999999   3899998               999999999999999
16   9999999999999999999996   999993              4999999999999999
17   99999999999999999999961  999993              9999999999999999
18   99999999999999999999991 1599994             59999999999999999
19   99999999999999999999992 1699994            169999999999999999
20   99999999999999999999998  699995            199999999999999999
21   99999999999999999999998  799996            799999999999999999
22   999999999999999999999993 799996           2899999999999999999
23   999999999999999999999994 899996           2999999999999999999
24   999999999999999999999994 299997           8999999999999999999
25   9999999999999999999999951 399997          9999999999999999999
26   9999999999999999999999991 399998         49999999999999999999
27   9999999999999999999999992 499998         49999999999999999999
28   9999999999999999999999992 499998         59999999999999999999
29   9999999999999999999999992 599999        199999999999999999999
30   99999999999999999999999961599999        199999999999999999999
```

(S) Fig. 7—P_d of 3000-m^2 target at 1000-n.mi. range in approaching sea clutter, σ_0 = -17 dB

RADIAL SPEED (KNOTS)

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

5	999999999961	13321	3
6	99999999999982	25421	1599
7	999999999999994	147542	279999
8	99999999999999961	158754	48999999
9	999999999999999971	29865	599999999
10	9999999999999999982	1379761	16999999999
11	9999999999999999993	1489871	279999999999
12	99999999999999999994	599982	2899999999999
13	99999999999999999995	299992	39999999999999
14	999999999999999999991	399993	49999999999999
15	999999999999999999997	499994	599999999999999
16	9999999999999999999971	58999	1999999999999999
17	9999999999999999999992	59999	6999999999999999
18	9999999999999999999998	199991	17999999999999999
19	9999999999999999999999	199991	29999999999999999
20	99999999999999999999994	299991	89999999999999999
21	99999999999999999999994	299991	399999999999999999
22	99999999999999999999995	399992	399999999999999999
23	99999999999999999999999	389992	999999999999999999
24	999999999999999999999991	99993	4999999999999999999
25	999999999999999999999991	99993	5999999999999999999
26	999999999999999999999997	99994	15999999999999999999
27	999999999999999999999997	199994	19999999999999999999
28	999999999999999999999997	199994	19999999999999999999
29	999999999999999999999998	199995	69979999999999999999
30	9999999999999999999999992	199995	79999999999999999999

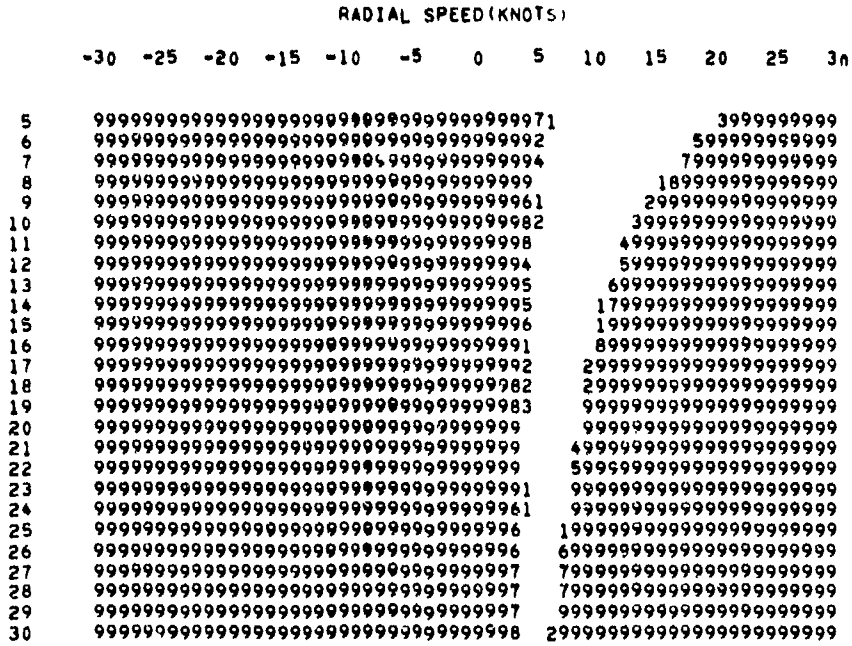
(S) Fig. 8—P_d of 3000-m^2 target at 1500-n.mi range in approaching sea clutter, σ_0 = -17 dB

RADIAL SPEED (KNOTS)

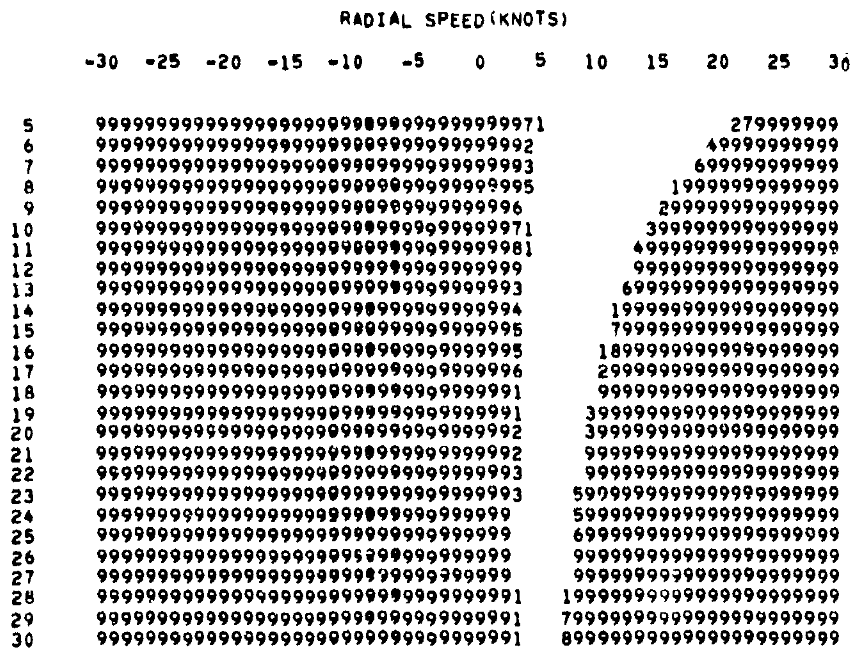
-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

5	99999999983	11	1
6	99999999999951	21	279
7	999999999999971	1421	48999
8	9999999999999983	25421	15999999
9	99999999999999994	6532	269999999
10	999999999999999995	14653	3999999999
11	9999999999999999991	25854	49999999999
12	99999999999999999971	26965	599999999999
13	99999999999999999992	7976	16999999999999
14	99999999999999999998	189861	19999999999999
15	999999999999999999994	199971	279999999999999
16	999999999999999999994	25998	899999999999999
17	999999999999999999999	26998	3899999999999999
18	9999999999999999999995	7999	4999999999999999
19	9999999999999999999996	7999	9999999999999999
20	99999999999999999999971	8999	59999999999999999
21	99999999999999999999991	8999	199999999999999999
22	99999999999999999999992	19999	199999999999999999
23	99999999999999999999998	15999	699999999999999999
24	99999999999999999999998	69991	1799999999999999999
25	99999999999999999999999	69991	2999999999999999999
26	999999999999999999999983	79991	2999999999999999999
27	999999999999999999999994	79991	· 29 [illegible]999999999999999
28	999999999999999999999994	79991	8999999999999999999
29	999999999999999999999995	89992	39999999999999999999
30	999999999999999999999999	89992	49999999999999999999

(S) Fig. 9—P_d of 3000-m^2 target at 2000-n.mi. range in approaching sea clutter, σ_0 = -17 dB



(S) Fig. 10—P_d of 50,000-m^2 target at 500-n.mi. range in approaching sea clutter, σ_0 = -17 dB



(S) Fig. 11—P_d of 50,000-m^2 target at 1000-n.mi. range in approaching sea clutter, σ_0 = -17 dB

```
                     RADIAL SPEED(KNOTS)

     -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5     999999999999999999756609999999999993                 27799999
 6     99999999999999999999789999999999995               14999999999
 7     99999999999999999999999999999999996              269999999999
 8     999999999999999999999999999999999981            7999999999999
 9     99999999999999999999999999999999992            99999999999999
10     99999999999999999999999999999999993           599999999999999
11     99999999999999999999999999999999994         16999999999999999
12     99999999999999999999999999999999995        799999999999999999
13     9999999999999999999999999999999999         289999999999999999
14     99999999999999999999999999999999991        999999999999999999
15     99999999999999999999999999999999991       3999999999999999999
16     99999999999999999999999999999999981       4999999999999999999
17     99999999999999999999999999999999992       9999999999999999999
18     9999999999999999999999999999999999       59999999999999999999
19     9999999999999999999999999999999999       69999999999999999999
20     9999999999999999999999999999999999       99999999999999999999
21     9999999999999999999999999999999999      799999999999999999999
22     9999999999999999999999999999999999      799999999999999999999
23     9999999999999999999999999999999995     1799999999999999999999
24     9999999999999999999999999999999995     1999999999999999999999
25     9999999999999999999999999999999996     2999999999999999999999
26     9999999999999999999999999999999996     9999999999999999999999
27     9999999999999999999999999999999997     9999999999999999999999
28     9999999999999999999999999999999997     9999999999999999999999
29     9999999999999999999999999999999997    39999999999999999999999
30     9999999999999999999999999999999998    39999999999999999999999
```

(S) Fig. 12—P_d of 50,000-m^2 target at 1500-n.mi. range in approaching sea clutter, σ_0 = −17 dB

```
                     RADIAL SPEED(KNOTS)

     -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5     999999999999999996423389999999999771                144999999
 6     99999999999999999986459999999999982                2699999999
 7     99999999999999999998679999999999993               38999999999
 8     99999999999999999999978999999999995             5999999999999
 9     9999999999999999999999899999999999             69999999999999
10     99999999999999999999999999999999971           299999999999999
11     99999999999999999999999999999999981          3899999999999999
12     99999999999999999999999999999999992         49999999999999999
13     9999999999999999999999999999999999          59999999999999999
14     9999999999999999999999999999999999         699999999999999999
15     9999999999999999999999999999999999        1699999999999999999
16     9999999999999999999999999999999995        1999999999999999999
17     9999999999999999999999999999999996        8999999999999999999
18     9999999999999999999999999999999996       29999999999999999999
19     9999999999999999999999999999999997       29999999999999999999
20     9999999999999999999999999999999997       99999999999999999999
21     9999999999999999999999999999999998      499999999999999999999
22     9999999999999999999999999999999998      499999999999999999999
23     9999999999999999999999999999999992      599999999999999999999
24     9999999999999999999999999999999992      999999999999999999999
25     9999999999999999999999999999999993      999999999999999999999
26     9999999999999999999999999999999993     6999999999999999999999
27     9999999999999999999999999999999994     6999999999999999999999
28     9999999999999999999999999999999994     7999999999999999999999
29     9999999999999999999999999999999994    19999999999999999999999
30     999999999999999999999999,999999995    19999999999999999999999
```

(S) Fig. 13—P_d of 50,000-m^2 target at 2000 n.mi. range in approaching sea clutter, σ_0 = −17 dB

```
                            RADIAL SPEED(KNOTS)

       -30  -25  -20  -15  -10  -5   0    5    10   15   20   25   30

 5     951                                                       159
 6     99972                         1                         27999
 7     9999983                       2                       3899999
 8     9999999951                   131                   1599999999
 9     99999999961                  252                  16999999999
10     999999999972                 363                 279999999999
11     9999999999983                474                3899999999999
12     99999999999994               585               49999999999999
13     99999999999999               686               99999999999999
14     9999999999999951             696             1599999999999999
15     9999999999999991             797             1999999999999999
16     9999999999999997             393             7999999999999999
17     99999999999999992            494            29999999999999999
18     99999999999999998           15951           89999999999999999
19     999999999999999993          15951          399999999999999999
20     999999999999999994          16961          499999999999999999
21     9999999999999999991          696          1999999999999999999
22     9999999999999999995          797          5999999999999999999
23     9999999999999999995          797          5999999999999999999
24     99999999999999999991         898         19999999999999999999
25     99999999999999999992         898         29999999999999999999
26     99999999999999999997         898         79999999999999999999
27     99999999999999999997         999         79999999999999999999
28     99999999999999999997         999         79999999999999999999
29     999999999999999999993        999        399999999999999999999
30     999999999999999999993        999        399999999999999999999
```

(S) Fig. 14—P_d of a 1000-m^2 target at 500-n.mi. range in crosswind sea clutter, σ_0 = -17 dB

```
                            RADIAL SPEED(KNOTS)

       -30  -25  -20  -15  -10  -5   0    5    10   15   20   25   30

 5     2                                                           2
 6     9841                                                     1489
 7     999961                                                 169999
 8     99999973                                             37999999
 9     999999984                                           489999999
10     99999999951                                       15999999999
11     999999999961                  1                  169999999999
12     9999999999972                 1                 2799999999999
13     99999999999983                1                38999999999999
14     99999999999993                2                39999999999999
15     999999999999994              131              499999999999999
16     9999999999999991              3              1999999999999999
17     9999999999999995              4              5999999999999999
18     99999999999999961             5             16999999999999999
19     99999999999999992             5             29999999999999999
20     99999999999999997             6             79999999999999999
21     999999999999999992            6            299999999999999999
22     999999999999999993           171           399999999999999999
23     999999999999999999           171           999999999999999999
24     9999999999999999994          181          4999999999999999999
25     9999999999999999994          181          4999999999999999999
26     9999999999999999995          191          5999999999999999999
27     99999999999999999991         292         19999999999999999999
28     99999999999999999991         292         19999999999999999999
29     99999999999999999996         292         69999999999999999999
30     99999999999999999996         393         69999999999999999999
```

(S) Fig. 15—P_d of a 1000-m^2 target at 1000-n.mi. range in crosswind sea clutter, σ_0 = -17 dB

```
                              RADIAL SPEED(KNOTS)

        -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30


 5
 6      841                                                     148
 7      99962                                                 26999
 8      9999973                                             3799999
 9      999999941                                         149999999
10      9999999991                                       1999999999
11      99999999992                                     29999999999
12      999999999993                                   399999999999
13      9999999999984                                 4899999999999
14      9999999999999                                 9999999999999
15      999999999999951                             159999999999999
16      999999999999996                             699999999999999
17      9999999999999961             1             1699999999999999
18      9999999999999992             1             2999999999999999
19      9999999999999998             1             8999999999999999
20      99999999999999993            2            39999999999999999
21      99999999999999999            2            99999999999999999
22      99999999999999999            3            99999999999999999
23      999999999999999994           3           499999999999999999
24      9999999999999999951          4          1599999999999999999
25      9999999999999999991          4          1999999999999999999
26      9999999999999999991          4          1999999999999999999
27      9999999999999999996          5          6999999999999999999
28      9999999999999999997          5          7999999999999999999
29      99999999999999999992         6         29999999999999999999
30      99999999999999999992         6         29999999999999999999
```

(S) Fig. 16—P_d of a 1000-m^2 target at 1500-n.mi. range in crosswind sea clutter, σ_0 = -17 dB

```
                              RADIAL SPEED(KNOTS)

        -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30


 5
 6      51                                                       15
 7      9873                                                   3789
 8      9999841                                             1489999
 9      9999991                                             1999999
10      999999996                                         699999999
11      9999999997                                       7999999999
12      999999999981                                   189999999999
13      9999999999951                                 1599999999999
14      9999999999996                                 6999999999999
15      99999999999992                               29999999999999
16      999999999999973                             379999999999999
17      999999999999993                             399999999999999
18      999999999999998                             899999999999999
19      9999999999999995                           5999999999999999
20      99999999999999991                         19999999999999999
21      99999999999999996                         69999999999999999
22      99999999999999996            1            69999999999999999
23      999999999999999992           1           999999999999999999
24      999999999999999992           1           999999999999999999
25      999999999999999997           1           999999999999999999
26      999999999999999998           2           899999999999999999
27      9999999999999999993          2          3999999999999999999
28      9999999999999999994          2          4999999999999999999
29      9999999999999999999          2          9999999999999999999
30      9999999999999999999          3          9999999999999999999
```

(S) Fig. 17—P_d of a 1000-m^2 target at 2000-n.mi. range in crosswind sea clutter, σ_0 = -17 dB

```
                              RADIAL SPEED(KNOTS)

      -30  -25  -20  -15  -10    -5    0    5   10   15   20   25   30

  5   99961                       37973                           16999
  6   99999883                   1599951                       38899999
  7   9999999951                 1699961                     1599999999
  8   999999999961               3899983                   169999999999
  9   9999999999972              4999994                  2799999999999
 10   99999999999984              99999                  48999999999999
 11   999999999999991            1699961                199999999999999
 12   9999999999999961           1799971               1699999999999999
 13   9999999999999996           1899981               6999999999999999
 14   99999999999999992          2999992              29999999999999999
 15   99999999999999998          3999993              89999999999999999
 16   999999999999999984          99999              489999999999999999
 17   9999999999999999991         99999             1999999999999999999
 18   9999999999999999995         99999             5999999999999999999
 19   9999999999999999996         99999             6999999999999999999
 20   99999999999999999992        99999            29999999999999999999
 21   99999999999999999992       1699961           29999999999999999999
 22   99999999999999999997       1799971           79999999999999999999
 23   99999999999999999998        79997            89999999999999999999
 24   999999999999999999994       89998           499999999999999999999
 25   999999999999999999994       89998           499999999999999999999
 26   999999999999999999999       99999           999999999999999999999
 27   999999999999999999999       99999           999999999999999999999
 28   999999999999999999999       99999           999999999999999999999
 29   9999999999999999999996      99999          6999999999999999999999
 30   9999999999999999999996      99999          6999999999999999999999
```

(S) Fig. 18—P_d of a 3000-m^2 target at 500-n.mi. range in crosswind sea clutter, σ_0 = -17 dB

```
                              RADIAL SPEED(KNOTS)

      -30  -25  -20  -15  -10    -5    0    5   10   15   20   25   30

  5   994                          131                              499
  6   9999611                      252                          1169999
  7   9999982                      363                         28999999
  8   9999999994                  15851                       499999999
  9   99999999951                 26962                     15999999999
 10   999999999961                37973                    169999999999
 11   9999999999972                898                    2799999999999
 12   9999999999998               19991                   8999999999999
 13   99999999999994              19991                  49999999999999
 14   999999999999994             19991                 499999999999999
 15   9999999999999951            29992                1599999999999999
 16   9999999999999991            38983                1999999999999999
 17   99999999999999962           38983               26999999999999999
 18   99999999999999992           49994               29999999999999999
 19   99999999999999998           49994               89999999999999999
 20   999999999999999983          59995              389999999999999999
 21   999999999999999994           999               499999999999999999
 22   9999999999999999991          999              1999999999999999999
 23   9999999999999999991         19991             1999999999999999999
 24   9999999999999999995         19991             5999999999999999999
 25   9999999999999999996         19991             6999999999999999999
 26   99999999999999999992        19991            29999999999999999999
 27   99999999999999999992        29992            29999999999999999999
 28   99999999999999999992        29992            29999999999999999999
 29   99999999999999999997        29992            79999999999999999999
 30   99999999999999999998        39993            89999999999999999999
```

(S) Fig. 19—P_d of a 3000-m^2 target at 1000-n.mi. range in crosswind sea clutter, σ_0 = -17 dB

```
                              RADIAL SPEED(KNOTS)

       -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

  5    951                                                          159
  6    99972                        1                             27999
  7    9999993                      2                           3999999
  8    9999999951                 141                        1599999999
  9    99999999961                252                       16999999999
 10    999999999972               363                      279999999999
 11    9999999999983              474                     3899999999999
 12    99999999999994             585                    49999999999999
 13    99999999999999             696                    99999999999999
 14    9999999999999961           696                  1699999999999999
 15    9999999999999991           797                  1999999999999999
 16    9999999999999997           494                  7999999999999999
 17    99999999999999992          494                 29999999999999999
 18    99999999999999998        15951                 89999999999999999
 19    999999999999999993       15951                399999999999999999
 20    999999999999999994       16961                499999999999999999
 21    9999999999999999991        696               1999999999999999999
 22    9999999999999999995        797               5999999999999999999
 23    9999999999999999995        797               5999999999999999999
 24    99999999999999999991       898              19999999999999999999
 25    99999999999999999992       898              29999999999999999999
 26    99999999999999999997       999              79999999999999999999
 27    99999999999999999997       999              79999999999999999999
 28    99999999999999999997       999              79999999999999999999
 29    999999999999999999993      999             399999999999999999999
 30    999999999999999999994      999             499999999999999999999
```

(S) Fig. 20—P_d of a 3000-m^2 target at 1500-n.mi. range in crosswind sea clutter, σ_0 = -17 dB

```
                              RADIAL SPEED(KNOTS)

       -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

  5    62                                                            26
  6    9984                                                        4899
  7    9999961                                                  1699999
  8    99999972                     1                         279999999
  9    9999999983                   2                        3899999999
 10    99999999994                131                       49999999999
 11    9999999999951              141                     1599999999999
 12    99999999999961             252                    16999999999999
 13    99999999999997             363                    79999999999999
 14    999999999999982            363                   289999999999999
 15    999999999999998            474                   899999999999999
 16    9999999999999994           181                  4999999999999999
 17    9999999999999999           181                  9999999999999999
 18    99999999999999995          292                 59999999999999999
 19    999999999999999961         292                169999999999999999
 20    999999999999999991         393                199999999999999999
 21    999999999999999997         393                999999999999999999
 22    9999999999999999972        494               2799999999999999999
 23    9999999999999999992        494               2999999999999999999
 24    9999999999999999998        595               8999999999999999999
 25    9999999999999999999        595               9999999999999999999
 26    99999999999999999994       696              49999999999999999999
 27    99999999999999999994       696              49999999999999999999
 28    99999999999999999995       696              59999999999999999999
 29    999999999999999999991      797             199999999999999999999
 30    999999999999999999991      797             199999999999999999999
```

(S) Fig. 21—P_d of a 3000-m^2 target at 2000-n.mi. range in crosswind sea clutter, σ_0 = -17 dB

```
                         RADIAL SPEED(KNOTS)

        -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5      99999999993            179999999999999971            39999999999
 6      99999999999995          3999999999999993           5999999999999
 7      9999999999999971        5999999999999995         179999999999999
 8      99999999999999981       1699999999999961       18999999999999999
 9      999999999999999992      2799999999999972      299999999999999999
10      9999999999999999993     3999999999999993     3999999999999999999
11      9999999999999999999      4999999999994       9999999999999999999
12      99999999999999999995    1599999999999951    59999999999999999999
13      999999999999999999991    6999999999996     199999999999999999999
14      999999999999999999997    1999999999991     799999999999999999999
15      9999999999999999999982   2999999999992    2899999999999999999999
16      9999999999999999999992   3899999999983    2999999999999999999999
17      9999999999999999999999   3999999999993    9999999999999999999999
18      99999999999999999999994  1999999999991   49999999999999999999999
19      99999999999999999999994  1999999999991   49999999999999999999999
20      99999999999999999999995  1599999999951   59999999999999999999999
21      999999999999999999999991  69999999996   199999999999999999999999
22      999999999999999999999991  69999999996   199999999999999999999999
23      999999999999999999999996  79999999997   699999999999999999999999
24      999999999999999999999997  79999999997   799999999999999999999999
25      999999999999999999999997  39999999993   799999999999999999999999
26      9999999999999999999999992 39999999993  2999999999999999999999999
27      9999999999999999999999992 49999999994  2999999999999999999999999
28      9999999999999999999999993 49999999994  3999999999999999999999999
29      9999999999999999999999993 59999999995  3999999999999999999999999
30      9999999999999999999999999 19999999991  9999999999999999999999999
```

(S) Fig. 22—P_d of a 50,000-m^2 target at 500-n.mi. range in crosswind sea clutter, σ_0 = -17 dB

```
                         RADIAL SPEED(KNOTS)

        -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5      9999999993              1799999999999971              3999999999
 6      999999999995             28999999999982             599999999999
 7      9999999999996            39999999999993            6999999999999
 8      999999999999981           99999999999            189999999999999
 9      99999999999999992        16999999999961        29999999999999999
10      999999999999999993       17999999999971       399999999999999999
11      9999999999999999994       89999999998        4999999999999999999
12      9999999999999999995       39999999993        9999999999999999999
13      99999999999999999996      49999999994       69999999999999999999
14      999999999999999999971     59999999995      179999999999999999999
15      999999999999999999991     69999999996      199999999999999999999
16      999999999999999999998     19999999991      899999999999999999999
17      9999999999999999999992    29999999992     2999999999999999999999
18      9999999999999999999992    27999999972     2999999999999999999999
19      9999999999999999999999    38999999983     9999999999999999999999
20      9999999999999999999999     999999999      9999999999999999999999
21      99999999999999999999994    999999999     49999999999999999999999
22      99999999999999999999995    999999999     59999999999999999999999
23      99999999999999999999999    999999999     99999999999999999999999
24      99999999999999999999999   15999999951    99999999999999999999999
25      999999999999999999999991   699999996    199999999999999999999999
26      999999999999999999999996   699999996    699999999999999999999999
27      999999999999999999999997   699999996    799999999999999999999999
28      999999999999999999999997   799999997    799999999999999999999999
29      999999999999999999999999   799999997    999999999999999999999999
30      9999999999999999999999992  799999997   2999999999999999999999999
```

(S) Fig. 23—P_d of a 50,000-m^2 target at 1000-n.mi. range in crosswind sea clutter, σ_0 = -17 dB

```
                         RADIAL SPEED(KNOTS)

      •30  -25  -20  -15  •10   •5    0    5   10   15   20   25   30

  5     999999995                2999999999992                  599999999
  6     999999999971              49999999994                179999999999
  7     9999999999982             69999999996               2899999999999
  8     99999999999994            79999999997              49999999999999
  9     999999999999995           29999999992             599999999999999
 10     9999999999999996          39999999993            6999999999999999
 11     999999999999999971        49999999994          179999999999999999
 12     999999999999999991         999999999           199999999999999999
 13     9999999999999999992       16999999961         2999999999999999999
 14     9999999999999999992       16999999961         2999999999999999999
 15     9999999999999999999       17999999971         9999999999999999999
 16     99999999999999999994       899999998         49999999999999999999
 17     99999999999999999995       899999998         59999999999999999999
 18     99999999999999999999       399999993         99999999999999999999
 19     999999999999999999996      499999994        699999999999999999999
 20     999999999999999999996      499999994        699999999999999999999
 21     9999999999999999999991     599999995       1999999999999999999999
 22     9999999999999999999991     599999995       1999999999999999999999
 23     9999999999999999999998     699999996       8999999999999999999999
 24     9999999999999999999998     199999991       8999999999999999999999
 25     9999999999999999999999     199999991       9999999999999999999999
 26     99999999999999999999992    299999992      29999999999999999999999
 27     99999999999999999999992    299999992      29999999999999999999999
 28     99999999999999999999993    299999992      39999999999999999999999
 29     99999999999999999999999    399999993      99999999999999999999999
 30     99999999999999999999999    399999993      99999999999999999999999
```

(S) Fig. 24—P_d of a 50,000-m^2 target at 1500-n.mi. range in crosswind sea clutter, σ_0 = -17 dB

```
                         RADIAL SPEED(KNOTS)

      •30  •25  -20  -15  •10   •5    0    5   10   15   20   25   30

  5     999999972                 69999999996                   279999999
  6     99999999994               28999999982                 49999999999
  7     999999999996              39999999993                699999999999
  8     99999999999991            49999999994              19999999999999
  9     999999999999992            699999996              299999999999999
 10     9999999999999993          17999999971            3999999999999999
 11     99999999999999994         18999999981           49999999999999999
 12     99999999999999999          999999999            99999999999999999
 13     999999999999999996         399999993           499999999999999999
 14     9999999999999999991        399999993          1999999999999999999
 15     9999999999999999997        499999994          7999999999999999999
 16     99999999999999999981       599999995         18999999999999999999
 17     99999999999999999992       699999996         29999999999999999999
 18     99999999999999999999       199999991         99999999999999999999
 19     999999999999999999993      199999991        399999999999999999999
 20     999999999999999999993      299999992        399999999999999999999
 21     999999999999999999999      299999992        999999999999999999999
 22     999999999999999999999      299999992        999999999999999999999
 23     9999999999999999999995     399999993       5999999999999999999999
 24     9999999999999999999995      9999999        5999999999999999999999
 25     9999999999999999999996      9999999        6999999999999999999999
 26     9999999999999999999999      9999999        9999999999999999999999
 27     9999999999999999999999      9999999        9999999999999999999999
 28     99999999999999999999991    199999991      19999999999999999999999
 29     99999999999999999999997    199999991      79999999999999999999999
 30     99999999999999999999998    199999991      89999999999999999999999
```

(S) Fig. 25—P_d of a 50,000-m^2 target at 2000-n.mi. range in crosswind sea clutter, σ_0 = -17 dB

```
                          RADIAL SPEED(KNOTS)

       -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5      999999999999994       27999999971                        2899
 6      99999999999999961      4999999993                     4499999
 7      999999999999999971    15999999994                   169999999
 8      9999999999999999993    1799999996                 27999999999
 9      999999999999999999941  28999999971               389999999999
10      999999999999999999961  4999999998               4999999999999
11      9999999999999999999961  599999993              59999999999999
12      999999999999999999997311699999994             199999999999999
13      999999999999999999999421699999995            2799999999999999
14      999999999999999999999981299999995            8999999999999999
15      999999999999999999999962299999996           48999999999999999
16      999999999999999999990643899999997          149999999999999999
17      999999999999999999999905499999997          599999999999999999
18      999999999999999999999906499999998         1699999999999999999
19      999999999999999999999998499999998         2999999999999999999
20      999999999999999999999008569999999         7999999999999999999
21      999999999999999999999009769999993         7999999999999999999
22      999999999999999999999009879999993        39999999999999999999
23      999999999999999999999009879999994        39999999999999999999
24      999999999999999999999009879999994        89999999999999999999
25      999999999999999999999009979999995       199999999999999999999
26      999999999999999999999009079999995       599999999999999999999
27      999999999999999999999009889999995       599999999999999999999
28      999999999999999999999009889999996       699999999999999999999
29      999999999999999999999009099999996      1999999999999999999999
30      999999999999999699990099999999996      2999999999999999999999
```

(S) Fig. 26—P_d of a 1000-m^2 target at 500-n.mi. range in approaching sea clutter, σ_0 = -23 dB

```
                          RADIAL SPEED(KNOTS)

       -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5      99999999999822         137999761                          169
 6      999999999999994         25999982                        28999
 7      99999999999999961       37999993                      4999999
 8      999999999999999971       8999995                    159999999
 9      9999999999999999982     169999961                 17999999999
10      9999999999999999999     279999971                289999999999
11      99999999999999999995     8999998                3999999999999
12      999999999999999999991    4999999               49999999999999
13      999999999999999999996    5999999              199999999999999
14      9999999999999999999972   5999999             1699999999999999
15      9999999999999999999992   6999999             1999999999999999
16      9999999999999999999899   1999996             7999999999999999
17      99999999999999999999993  29999961           29999999999999999
18      99999999999999999999994  28999971           89999999999999999
19      999999999999999999999951 38999971          499999999999999999
20      999999999999999999999901  9999982          499999999999999999
21      9999999999999999999999921 999998          1999999999999999999
22      9999999999999999999999061 999999          5999999999999999999
23      99999999999999999999990711999999          6999999999999999999
24      99999999999999999999990711699999         19999999999999999999
25      99999999999999999999990741699999         29999999999999999999
26      99999999999999999999990941699999         79999999999999999999
27      99999999999999999999990941799999         79999999999999999999
28      99999999999999999999990991799999         89999999999999999999
29      99999999999999999999990951899999        399999999999999999999
30      99999999999999999999999904899999        499999999999999999999
```

(S) Fig. 27—P_d of a 1000-m^2 target at 1000-n.mi. range in approaching sea clutter, σ_0 = -23 dB

RADIAL SPEED(KNOTS)

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

5	999999999994	366532	26
6	999999999999961	158754	4899
7	9999999999999972	379875	1599999
8	99999999999999993	4899871	179999999
9	999999999999999994	2599982	2899999999
10	9999999999999999995	3699993	39999999999
11	99999999999999999961	4799994	599999999999
12	99999999999999999997	899995	15999999999999
13	999999999999999999982	1599995	69999999999999
14	999999999999999999993	1699996	279999999999999
15	999999999999999999999	2799997	899999999999999
16	9999999999999999999994	899992	3999999999999999
17	9999999999999999999995	899992	9999999999999999
18	99999999999999999999991	499993	49999999999999999
19	99999999999999999999991	499993	59999999999999999
20	99999999999999999999997	599994	199999999999999999
21	99999999999999999999997	599994	699999999999999999
22	999999999999999999999982	699995	1699999999999999999
23	999999999999999999999992	699995	2999999999999999999
24	999999999999999999999993	199996	7999999999999999999
25	999999999999999999999993	299996	8999999999999999999
26	9999999999999999999999991	299997	38999999999999999999
27	9999999999999999999999991	299997	39999999999999999999
28	9999999999999999999999991	399997	39999999999999999999
29	9999999999999999999999991	399998	99999999999999999999
30	9999999999999999999999995	499998	99999999999999999999

(S) Fig. 28—P_d of a 1000-m^2 target at 1500-n.mi. range in approaching sea clutter, σ_0 = -23 dB

RADIAL SPEED(KNOTS)

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

5	999999999961	13321	3
6	99999999999983	25421	1599
7	999999999999994	147542	279999
8	99999999999999961	158754	48999999
9	999999999999999971	29865	599999999
10	9999999999999999982	1379761	16999999999
11	9999999999999999993	1589871	279999999999
12	99999999999999999994	599982	2899999999999
13	99999999999999999995	299992	39999999999999
14	999999999999999999991	399993	49999999999999
15	999999999999999999997	499994	599999999999999
16	9999999999999999999972	58999	1999999999999999
17	9999999999999999999992	59999	6999999999999999
18	9999999999999999999998	199991	17999999999999999
19	9999999999999999999999	199991	29999999999999999
20	99999999999999999999994	299991	89999999999999999
21	99999999999999999999994	299991	399999999999999999
22	99999999999999999999995	399992	399999999999999999
23	99999999999999999999999	389992	999999999999999999
24	999999999999999999999991	99993	4999999999999999999
25	999999999999999999999991	99993	5999999999999999999
26	999999999999999999999997	99994	15999999999999999999
27	999999999999999999999997	199994	19999999999999999999
28	999999999999999999999997	199994	19999999999999999999
29	999999999999999999999998	199995	69999999999999999999
30	9999999999999999999999992	199995	79999999999999999999

(S) Fig. 29—P_d of a 1000-m^2 target at 2000-n.mi. range in approaching sea clutter, σ_0 = -23 dB

```
                          RADIAL SPEED(KNOTS)

         -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

  5      99999999999999996422289999999999966                       4489999
  6      99999999999999999764499999999999981                    1699999999
  7      99999999999999999975699999999999993                   27999999999
  8      99999999999999999987799999999999994                 4899999999999
  9      9999999999999999999989999999999999                 59999999999999
 10      9999999999999999999999999999999996                299999999999999
 11      99999999999999999999999999999999971              3799999999999999
 12      99999999999999999999999999999999982             48999999999999999
 13      9999999999999999999999999999999999              49999999999999999
 14      9999999999999999999999999999999999             599999999999999999
 15      9999999999999999999999999999999999             699999999999999999
 16      9999999999999999999999999999999994            1999999999999999999
 17      9999999999999999999999999999999995            7999999999999999999
 18      9999999999999999999999999999999996           29999999999999999999
 19      9999999999999999999999999999999996           29999999999999999999
 20      9999999999999999999999999999999997           99999999999999999999
 21      9999999999999999999999999999999997          399999999999999999999
 22      9999999999999999999999999999999998          399999999999999999999
 23      99999999999999999999999999999999991         499999999999999999999
 24      9999999999999999999999999999999992          999999999999999999999
 25      9999999999999999999999999999999992          999999999999999999999
 26      9999999999999999999999999999999992         5999999999999999999999
 27      9999999999999999999999999999999993         6999999999999999999999
 28      9999999999999999999999999999999993         6999999999999999999999
 29      9999999999999999999999999999999994         9999999999999999999999
 30      9999999999999999999999999999999994        19999999999999999999999
```

(S) Fig. 30—P_d of a 3000-m^2 target at 500-n.mi. range in approaching sea clutter, σ_0 = -23 dB

```
                          RADIAL SPEED(KNOTS)

         -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

  5      9999999999999982    169999999995                            17999
  6      999999999999999041  2289999999971                        38899999
  7      9999999999999999681  499999999982                      1599999999
  8      99999999999999999731 169999999994                    169999999999
  9      99999999999999999984127899999995                    2799999999999
 10      999999999999999999964289999999999                  48999999999999
 11      9999999999999999999533899999999971                199999999999999
 12      9999999999999999999764999999999981               1699999999999999
 13      9999999999999999999864999999999992               6999999999999999
 14      9999999999999999999756999999999993              29999999999999999
 15      9999999999999999999967999999999993              89999999999999999
 16      999999999999999999998799999999999              499999999999999999
 17      999999999999999999999899999999999             1999999999999999999
 18      999999999999999999999899999999999             5999999999999999999
 19      999999999999999999999899999999999             6999999999999999999
 20      999999999999999999999999999999999            29999999999999999999
 21      9999999999999999999999999999999971           29999999999999999999
 22      9999999999999999999999999999999971           79999999999999999999
 23      999999999999999999999999999999998            89999999999999999999
 24      999999999999999999999999999999998           499999999999999999999
 25      999999999999999999999999999999999           499999999999999999999
 26      999999999999999999999999999999999           999999999999999999999
 27      999999999999999999999999999999999           999999999999999999999
 28      999999999999999999999999999999999           999999999999999999999
 29      999999999999999999999999999999999          6999999999999999999999
 30      999999999999999999999999999999999          6999999999999999999999
```

(S) Fig. 31—P_d of a 3000-m^2 target at 1000-n.mi. range in approaching sea clutter, σ_0 = -23 dB

```
                                   RADIAL SPEED(KNOTS)

      -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5    999999999999994        87999999971                       2899
 6    99999999999999961       4999999993                    4499999
 7    999999999999999972     15999999994                  169999999
 8    9999999999999999993     1799999996                27999999999
 9    999999999999999999941   28999999971              389999999999
10    999999999999999999961   4899999998              4999999999999
11    9999999999999999999961   599999993             59999999999999
12    9999999999999999999997311699999994            199999999999999
13    9999999999999999999996216999999995           2799999999999999
14    9999999999999999999999312999999995           8999999999999999
15    9999999999999999999996229999999996          48999999999999999
16    9999999999999999999996439999999997         149999999999999999
17    9999999999999999999999954999999997         599999999999999999
18    9999999999999999999999964999999998        1699999999999999999
19    9999999999999999999999984999999999        2999999999999999999
20    9999999999999999999999999569999999        7999999999999999999
21    9999999999999999999999997699999993        7999999999999999999
22    9999999999999999999999999879999993       39999999999999999999
23    9999999999999999999999999879999994       49999999999999999999
24    9999999999999999999999999979999994       99999999999999999999
25    9999999999999999999999999979999995      199999999999999999999
26    9999999999999999999999999979999995      599999999999999999999
27    9999999999999999999999999989999995      599999999999999999999
28    9999999999999999999999999989999996      699999999999999999999
29    9999999999999999999999999999999996     1999999999999999999999
30    9999999999999999999999999999999997     2999999999999999999999
```

(S) Fig. 32—P_d of a 3000-m^2 target at 1500-n.mi. range in approaching sea clutter, σ_0 = -23 dB

```
                                   RADIAL SPEED(KNOTS)

      -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5    999999999999771         489999994                         599
 6    9999999999999983        1699999961                    1179999
 7    99999999999999994       2799999981                   38999999
 8    9999999999999999961      499999993                 4999999999
 9    99999999999999999971    1599999994               169999999999
10    99999999999999999992    1699999995              1799999999999
11    999999999999999999993    299999991             28999999999999
12    9999999999999999999941   389999991             89999999999999
13    9999999999999999999991   399999992            499999999999999
14    99999999999999999999961   99999992           5999999999999999
15    99999999999999999999973  199999993          16999999999999999
16    9999999999999999999999931169999994          29999999999999999
17    9999999999999999999999982169999995         279999999999999999
18    9999999999999999999999983179999995         399999999999999999
19    9999999999999999999999995179999996         899999999999999999
20    9999999999999999999999996239999996        4899999999999999999
21    9999999999999999999999996439999991        4999999999999999999
22    9999999999999999999999999549999991       19999999999999999999
23    9999999999999999999999999549999991       19999999999999999999
24    9999999999999999999999999659999991       69999999999999999999
25    9999999999999999999999999849999992       69999999999999999999
26    9999999999999999999999999859999992      299999999999999999999
27    9999999999999999999999999959999992      299999999999999999999
28    9999999999999999999999999959999993      399999999999999999999
29    9999999999999999999999999969999993      899999999999999999999
30    9999999999999999999999999989999994      899999999999999999999
```

(S) Fig. 33—P_d of a 3000-m^2 target at 2000-n.mi. range in approaching sea clutter, σ_0 = -23 dB

```
                         RADIAL SPEED(KNOTS)

      -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

  5   9999999999999999999999999999999999999994         499999999999
  6   99999999999999999999999999999999999999661      6999999999999999
  7   9999999999999999999999999999999999999972     1799999999999999
  8   999999999999999999999999999999999999983     28999999999999999
  9   9999999999999999999999999999999999999941   499999999999999999
 10   999999999999999999999999999999999999991   5999999999999999999
 11   999999999999999999999999999999999999962  16999999999999999999
 12   99999999999999999999999999999999999997   79999999999999999999
 13   999999999999999999999999999999999999941 289999999999999999999
 14   999999999999999999999999999999999999951 399999999999999999999
 15   99999999999999999999999999999999999995  999999999999999999999
 16   99999999999999999999999999999999999992 4999999999999999999999
 17   9999999999999999999999999999999999999315999999999999999999999
 18   9999999999999999999999999999999999997319999999999999999999999
 19   9999999999999999999999999999999999998119999999999999999999999
 20   9999999999999999999999999999999999998179999999999999999999999
 21   9999999999999999999999999999999999995179999999999999999999999
 22   9999999999999999999999999999999999995289999999999999999999999
 23   9999999999999999999999999999999999996399999999999999999999999
 24   9999999999999999999999999999999999996399999999999999999999999
 25   9999999999999999999999999999999999993499999999999999999999999
 26   9999999999999999999999999999999999993999999999999999999999999
 27   9999999999999999999999999999999999994999999999999999999999999
 28   9999999999999999999999999999999999994999999999999999999999999
 29   9999999999999999999999999999999999994999999999999999999999999
 30   9999999999999999999999999999999999996999999999999999999999999
```

(S) Fig. 34—P_d of a 50,000-m^2 target at 500-n.mi. range in approaching sea clutter, σ_0 = -23 dB

```
                         RADIAL SPEED(KNOTS)

      -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

  5   999999999999999999999999999999999999982           39999999999
  6   99999999999999999999999999999999999994          5999999999999
  7   999999999999999999999999999999999999951       179999999999999
  8   99999999999999999999999999999999999971       1899999999999999
  9   99999999999999999999999999999999999982      29999999999999999
 10   99999999999999999999999999999999999994     499999999999999999
 11   9999999999999999999999999999999999995      999999999999999999
 12   99999999999999999999999999999999999961    6999999999999999999
 13   9999999999999999999999999999999999996    19999999999999999999
 14   9999999999999999999999999999999999992    79999999999999999999
 15   9999999999999999999999999999999999992   289999999999999999999
 16   9999999999999999999999999999999999983   299999999999999999999
 17   9999999999999999999999999999999999994   999999999999999999999
 18   9999999999999999999999999999999999991  4999999999999999999999
 19   9999999999999999999999999999999999991  4999999999999999999999
 20   9999999999999999999999999999999999951  5999999999999999999999
 21   999999999999999999999999999999999996  19999999999999999999999
 22   999999999999999999999999999999999996  19999999999999999999999
 23   999999999999999999999999999999999997  69999999999999999999999
 24   999999999999999999999999999999999997  79999999999999999999999
 25   999999999999999999999999999999999993  79999999999999999999999
 26   999999999999999999999999999999999994 299999999999999999999999
 27   999999999999999999999999999999999994 399999999999999999999999
 28   999999999999999999999999999999999995 399999999999999999999999
 29   999999999999999999999999999999999995 399999999999999999999999
 30   999999999999999999999999999999999992 999999999999999999999999
```

(S) Fig. 35—P_d of a 50,000-m^2 target at 1000-n.mi. range in approaching sea clutter, σ_0 = -23 dB

```
                              RADIAL SPEED(KNOTS)

       -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5      99999999999999999999999999999999999993             6999999999
 6      9999999999999999999999999999999999995           1899999999999
 7      99999999999999999999999999999999999971         39999999999999
 8      9999999999999999999999999999999999992         499999999999999
 9      9999999999999999999999999999999999994        5999999999999999
10      9999999999999999999999999999999999995       69999999999999999
11      9999999999999999999999999999999999991      799999999999999999
12      9999999999999999999999999999999999971     1899999999999999999
13      9999999999999999999999999999999999982     9999999999999999999
14      999999999999999999999999999999999998     39999999999999999999
15      999999999999999999999999999999999999     49999999999999999999
16      999999999999999999999999999999999994     99999999999999999999
17      9999999999999999999999999999999999951   599999999999999999999
18      999999999999999999999999999999999996   1699999999999999999999
19      999999999999999999999999999999999996   1999999999999999999999
20      999999999999999999999999999999999991   1999999999999999999999
21      999999999999999999999999999999999992   7999999999999999999999
22      999999999999999999999999999999999992   8999999999999999999999
23      999999999999999999999999999999999993  29999999999999999999999
24      999999999999999999999999999999999993  29999999999999999999999
25      99999999999999999999999999999999999   39999999999999999999999
26      999999999999999999999999999999999991  99999999999999999999999
27      999999999999999999999999999999999991  99999999999999999999999
28      999999999999999999999999999999999991  99999999999999999999999
29      999999999999999999999999999999999991  99999999999999999999999
30      99999999999999999999999999999999999  599999999999999999999999
```

(S) Fig. 36—P_d of a 50,000-m^2 target at 1500-n.mi. range in approaching sea clutter, σ_0 = -23 dB

```
                              RADIAL SPEED(KNOTS)

       -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5      99999999999999999999999999999999999971             3999999999
 6      9999999999999999999999999999999999992            599999999999
 7      9999999999999999999999999999999999994          17999999999999
 8      999999999999999999999999999999999999          189999999999999
 9      9999999999999999999999999999999999971        2999999999999999
10      9999999999999999999999999999999999982       39999999999999999
11      999999999999999999999999999999999999       499999999999999999
12      999999999999999999999999999999999994       599999999999999999
13      999999999999999999999999999999999995      6999999999999999999
14      999999999999999999999999999999999995     17999999999999999999
15      999999999999999999999999999999999996     19999999999999999999
16      999999999999999999999999999999999991     89999999999999999999
17      999999999999999999999999999999999992    299999999999999999999
18      999999999999999999999999999999999983    399999999999999999999
19      999999999999999999999999999999999993    999999999999999999999
20      99999999999999999999999999999999999     999999999999999999999
21      99999999999999999999999999999999999    4999999999999999999999
22      99999999999999999999999999999999999    5999999999999999999999
23      999999999999999999999999999999999991   9999999999999999999999
24      999999999999999999999999999999999961  19999999999999999999999
25      99999999999999999999999999999999996   19999999999999999999999
26      99999999999999999999999999999999996   69999999999999999999999
27      99999999999999999999999999999999997   79999999999999999999999
28      99999999999999999999999999999999997   79999999999999999999999
29      99999999999999999999999999999999998   99999999999999999999999
30      99999999999999999999999999999999998  299999999999999999999999
```

(S) Fig. 37—P_d of a 50,000-m^2 target at 2000-n.mi. range in approaching sea clutter, σ_0 = -23 dB

RADIAL SPEED(KNOTS)

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

5	99994	116999611	49999
6	999999961	3899983	169999999
7	9999999973	4999994	3799999999
8	999999999994	6999996	499999999999
9	99999999999951	7999997	15999999999999
10	99999999999997	2999992	79999999999999
11	999999999999993	2999992	399999999999999
12	9999999999999984	3999993	4899999999999999
13	99999999999999991	4999994	19999999999999999
14	999999999999999951	5999995	159999999999999999
15	999999999999999992	6999996	299999999999999999
16	999999999999999997	1999991	799999999999999999
17	9999999999999999993	1999991	3999999999999999999
18	9999999999999999998	1999991	8999999999999999999
19	9999999999999999999	2999992	9999999999999999999
20	99999999999999999995	2999992	59999999999999999999
21	99999999999999999995	2999992	59999999999999999999
22	99999999999999999999	3999993	99999999999999999999
23	999999999999999999991	99999	199999999999999999999
24	999999999999999999996	99999	699999999999999999999
25	999999999999999999997	99999	799999999999999999999
26	9999999999999999999991	99999	1999999999999999999999
27	9999999999999999999991	99999	1999999999999999999999
28	9999999999999999999992	99999	2999999999999999999999
29	9999999999999999999998	99999	8999999999999999999999
30	9999999999999999999999	99999	9999999999999999999999

(S) Fig. 38—P_d of a 1000-m^2 target at 500-n.mi. range in crosswind sea clutter, σ_0 = -23 dB

RADIAL SPEED(KNOTS)

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

5	9972	363	2799
6	9999944	15851	4499999
7	999999951	26962	159999999
8	99999999972	38983	27999999999
9	999999999983	1599951	389999999999
10	9999999999994	69996	4999999999999
11	99999999999995	29992	59999999999999
12	999999999999991	39993	199999999999999
13	9999999999999972	39993	2799999999999999
14	9999999999999997	49994	7999999999999999
15	99999999999999983	59995	38999999999999999
16	999999999999999941	69996	149999999999999999
17	999999999999999995	69996	599999999999999999
18	9999999999999999951	79997	1599999999999999999
19	9999999999999999991	79997	1999999999999999999
20	9999999999999999997	89998	7999999999999999999
21	9999999999999999997	29992	7999999999999999999
22	99999999999999999993	29992	39999999999999999999
23	99999999999999999993	39993	39999999999999999999
24	99999999999999999998	39993	89999999999999999999
25	999999999999999999991	49994	199999999999999999999
26	999999999999999999995	49994	599999999999999999999
27	999999999999999999995	59995	599999999999999999999
28	999999999999999999995	59995	599999999999999999999
29	9999999999999999999991	59995	1999999999999999999999
30	9999999999999999999992	69996	2999999999999999999999

(S) Fig. 39—P_d of a 1000-m^2 target at 1000-n.mi. range in crosswind sea clutter, σ_0 = -23 dB

RADIAL SPEED(KNOTS)

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

5	983	2	389
6	9999511	141	1159999
7	99999971	252	17999999
8	9999999983	474	3899999999
9	99999999994	15851	49999999999
10	9999999999951	26962	1599999999999
11	99999999999961	797	16999999999999
12	99999999999997	898	79999999999999
13	999999999999992	999	299999999999999
14	9999999999999983	19991	3899999999999999
15	9999999999999994	19991	4999999999999999
16	99999999999999991	27972	19999999999999999
17	999999999999999951	27972	159999999999999999
18	999999999999999991	38983	199999999999999999
19	999999999999999996	38983	699999999999999999
20	9999999999999999972	49994	2799999999999999999
21	9999999999999999993	999	3999999999999999999
22	9999999999999999998	999	8999999999999999999
23	9999999999999999998	999	8999999999999999999
24	99999999999999999994	999	49999999999999999999
25	99999999999999999995	19991	59999999999999999999
26	999999999999999999991	19991	199999999999999999999
27	999999999999999999991	19991	199999999999999999999
28	999999999999999999991	19991	199999999999999999999
29	999999999999999999996	19991	699999999999999999999
30	999999999999999999997	29992	799999999999999999999

(S) Fig. 40—P_d of a 1000-m^2 target at 1500-n.mi. range in crosswind sea clutter, σ_0 = -23 dB

RADIAL SPEED(KNOTS)

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

5	951		159
6	99972	1	27999
7	9999994	2	4999999
8	9999999951	141	1599999999
9	99999999961	252	16999999999
10	999999999972	363	279999999999
11	9999999999983	474	3899999999999
12	99999999999994	585	49999999999999
13	99999999999999	696	99999999999999
14	9999999999999961	696	1699999999999999
15	9999999999999991	797	1999999999999999
16	9999999999999997	494	7999999999999999
17	99999999999999992	494	29999999999999999
18	99999999999999998	15951	89999999999999999
19	999999999999999993	15951	399999999999999999
20	999999999999999994	16961	499999999999999999
21	9999999999999999991	696	1999999999999999999
22	9999999999999999995	797	5999999999999999999
23	9999999999999999996	797	6999999999999999999
24	99999999999999999991	898	19999999999999999999
25	99999999999999999992	898	29999999999999999999
26	99999999999999999997	999	79999999999999999999
27	99999999999999999997	999	79999999999999999999
28	99999999999999999998	999	89999999999999999999
29	999999999999999999993	999	399999999999999999999
30	999999999999999999994	999	499999999999999999999

(S) Fig. 41—P_d of a 1000-m^2 target at 2000-n.mi. range in crosswind sea clutter, σ_0 = -23 dB

```
                                RADIAL SPEED(KNOTS)

      -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5    999999962                    69999999996                 269999999
 6    99999999983                  18999999981               38999999999
 7    999999999995                 29999999992              599999999999
 8    99999999999991               49999999994            19999999999999
 9    999999999999991               599999995            199999999999999
10    9999999999999992              699999996           2999999999999999
11    99999999999999993            17999999971         39999999999999999
12    99999999999999999             899999998          99999999999999999
13    999999999999999995            299999992         599999999999999999
14    999999999999999999            399999993         999999999999999999
15    9999999999999999997           499999994        7999999999999999999
16    99999999999999999971          499999994       17999999999999999999
17    99999999999999999991          599999995       19999999999999999999
18    99999999999999999999          199999991       99999999999999999999
19    999999999999999999992         199999991      299999999999999999999
20    999999999999999999993         199999991      399999999999999999999
21    999999999999999999999         299999992      999999999999999999999
22    999999999999999999999         299999992      999999999999999999999
23    9999999999999999999994        289999982     4999999999999999999999
24    9999999999999999999995         9999999      5999999999999999999999
25    9999999999999999999995         9999999      5999999999999999999999
26    9999999999999999999999         9999999      9999999999999999999999
27    9999999999999999999999         9999999      9999999999999999999999
28    9999999999999999999999         9999999      9999999999999999999999
29    99999999999999999999997        9999999     79999999999999999999999
30    99999999999999999999997       199999991    79999999999999999999999
```

(S) Fig. 42—P_d of a 3000-m^2 target at 500-n.mi. range in crosswind sea clutter, σ_0 = -23 dB

```
                                RADIAL SPEED(KNOTS)

      -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5    9999833                       559999955                    3389999
 6    9999999951                    179999971                 1599999999
 7    99999999972                   289999982                27999999999
 8    9999999999984                 399999993              4899999999999
 9    99999999999995                 9999999              59999999999999
10    999999999999992                6999996             299999999999999
11    9999999999999972              179999971           2799999999999999
12    99999999999999983             189999981          38999999999999999
13    99999999999999994              8999998           49999999999999999
14    999999999999999995             9999999          599999999999999999
15    999999999999999996             9999999          699999999999999999
16    9999999999999999991            4999994         1999999999999999999
17    9999999999999999997            5999995         7999999999999999999
18    99999999999999999991           5999995        19999999999999999999
19    99999999999999999992           6999996        29999999999999999999
20    99999999999999999999           6999996        99999999999999999999
21    999999999999999999993          7999997       399999999999999999999
22    999999999999999999993          7999997       399999999999999999999
23    999999999999999999994          1999991       499999999999999999999
24    999999999999999999999          1999991       999999999999999999999
25    999999999999999999999          2999992       999999999999999999999
26    9999999999999999999995         2999992      5999999999999999999999
27    9999999999999999999996         2999992      6999999999999999999999
28    9999999999999999999996         3999993      6999999999999999999999
29    9999999999999999999999         3999993      9999999999999999999999
30    99999999999999999999991        4999994     19999999999999999999999
```

(S) Fig. 43—P_d of a 3000-m^2 target at 1000-n.mi. range in crosswind sea clutter, σ_0 = -23 dB

RADIAL SPEED(KNOTS)

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

5	99994	116999611	49999
6	999999961	3899983	169999999
7	9999999973	4999994	3799999999
8	9999999999941	6999996	1499999999999
9	99999999999951	7999997	15999999999999
10	99999999999997	2999992	79999999999999
11	999999999999993	2999992	399999999999999
12	9999999999999984	3999993	4899999999999999
13	99999999999999991	4999994	19999999999999999
14	999999999999999951	5999995	159999999999999999
15	999999999999999992	6999996	299999999999999999
16	999999999999999997	1999991	799999999999999999
17	9999999999999999993	1999991	3999999999999999999
18	9999999999999999998	1999991	8999999999999999999
19	9999999999999999999	2999992	9999999999999999999
20	99999999999999999995	2999992	59999999999999999999
21	99999999999999999995	2999992	59999999999999999999
22	99999999999999999999	3999993	99999999999999999999
23	999999999999999999991	99999	199999999999999999999
24	999999999999999999997	99999	799999999999999999999
25	999999999999999999997	99999	799999999999999999999
26	9999999999999999999991	99999	1999999999999999999999
27	9999999999999999999992	99999	2999999999999999999999
28	9999999999999999999992	99999	2999999999999999999999
29	9999999999999999999998	99999	8999999999999999999999
30	9999999999999999999999	99999	9999999999999999999999

(S) Fig. 44—P_d of a 3000-m^2 target at 1500-n.mi. range in crosswind sea clutter, σ_0 = -23 dB

RADIAL SPEED(KNOTS)

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

5	99961	37973	16999
6	99999883	1599951	38899999
7	9999999941	1699961	1499999999
8	999999999961	3899983	169999999999
9	9999999999972	4999994	2799999999999
10	99999999999983	99999	38999999999999
11	999999999999991	69996	199999999999999
12	9999999999999951	1799971	1599999999999999
13	9999999999999996	1899981	6999999999999999
14	99999999999999992	2899982	29999999999999999
15	99999999999999998	3999993	89999999999999999
16	999999999999999984	99999	489999999999999999
17	9999999999999999991	99999	1999999999999999999
18	9999999999999999995	99999	5999999999999999999
19	9999999999999999996	99999	6999999999999999999
20	99999999999999999992	99999	29999999999999999999
21	99999999999999999992	69996	29999999999999999999
22	99999999999999999997	1799971	79999999999999999999
23	99999999999999999998	79997	89999999999999999999
24	999999999999999999993	89998	399999999999999999999
25	999999999999999999994	89998	499999999999999999999
26	999999999999999999999	89998	999999999999999999999
27	999999999999999999999	99999	999999999999999999999
28	999999999999999999999	99999	999999999999999999999
29	9999999999999999999995	99999	5999999999999999999999
30	9999999999999999999996	99999	6999999999999999999999

(S) Fig. 45—P_d of a 3000-m^2 target at 2000-n.mi. range in crosswind sea clutter, σ_0 = -23 dB

```
                              RADIAL SPEED(KNOTS)

       -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

  5    99999999999955    1559999999999999999999551    55999999999999
  6    9999999999999971   37999999999999999999973   1799999999999999
  7    99999999999999983  14899999999999999999841  38999999999999999
  8    999999999999999994  269999999999999999962  499999999999999999
  9    99999999999999999961 7999999999999999997 16999999999999999999
 10    9999999999999999991148999999999999999998411999999999999999999
 11    9999999999999999998259999999999999999999528999999999999999999
 12    9999999999999999999326999999999999999996239999999999999999999
 13    9999999999999999999937999999999999999997399999999999999999999
 14    9999999999999999999995899999999999999985999999999999999999999
 15    9999999999999999999996599999999999999956999999999999999999999
 16    9999999999999999999999599999999999999995999999999999999999999
 17    9999999999999999999999799999999999999997999999999999999999999
 18    9999999999999999999999799999999999999997999999999999999999999
 19    9999999999999999999999879999999999999789999999999999999999999
 20    9999999999999999999999989999999999999989999999999999999999999
 21    9999999999999999999999989999999999999989999999999999999999999
 22    9999999999999999999999999999999999999999999999999999999999999
 23    9999999999999999999999999999999999999999999999999999999999999
 24    9999999999999999999999999999999999999999999999999999999999999
 25    9999999999999999999999999999999999999999999999999999999999999
 26    9999999999999999999999999999999999999999999999999999999999999
 27    9999999999999999999999999999999999999999999999999999999999999
 28    9999999999999999999999999999999999999999999999999999999999999
 29    9999999999999999999999999999999999999999999999999999999999999
 30    9999999999999999999999999999999999999999999999999999999999999
```

(S) Fig. 46—P_d of a 50,000-m^2 target at 500-n.mi. range in crosswind sea clutter, σ_0 = -23 dB

```
                              RADIAL SPEED(KNOTS)

       -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

  5    999999999994         3999999999999999993         499999999999
  6    99999999999995      155999999999999999551      59999999999999
  7    9999999999999971     1799999999999999971     1799999999999999
  8    99999999999999982     38999999999999983     28999999999999999
  9    999999999999999994   1499999999999999941   499999999999999999
 10    9999999999999999995   19999999999999991   5999999999999999999
 11    99999999999999999961  26999999999999962  16999999999999999999
 12    99999999999999999997   799999999999997   79999999999999999999
 13    999999999999999999982 13999999999999931 289999999999999999999
 14    999999999999999999993 14999999999999941 399999999999999999999
 15    999999999999999999999  599999999999995  999999999999999999999
 16    9999999999999999999994 299999999999992 4999999999999999999999
 17    9999999999999999999995129999999999999215999999999999999999999
 18    9999999999999999999991379999999999999731999999999999999999999
 19    9999999999999999999991179999999999999711999999999999999999999
 20    9999999999999999999997189999999999999817999999999999999999999
 21    9999999999999999999997159999999999999517999999999999999999999
 22    9999999999999999999998259999999999999528999999999999999999999
 23    9999999999999999999999369999999999999963999999999999999999999
 24    9999999999999999999999369999999999999963999999999999999999999
 25    9999999999999999999999439999999999999934999999999999999999999
 26    9999999999999999999999939999999999999939999999999999999999999
 27    9999999999999999999999949999999999999949999999999999999999999
 28    9999999999999999999999949999999999999949999999999999999999999
 29    9999999999999999999999949999999999999949999999999999999999999
 30    9999999999999999999999968999999999998699999999999999999999999
```

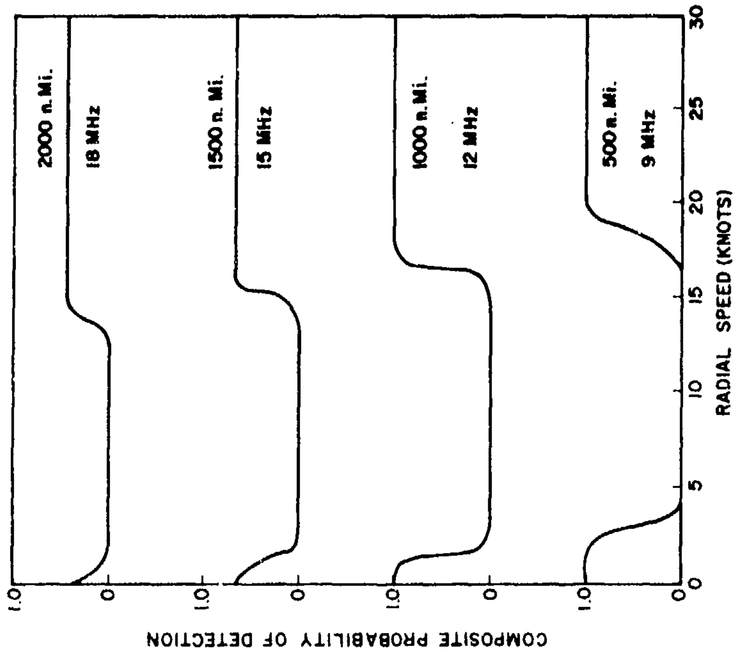
(S) Fig. 47—P_d of a 50,000-m^2 target at 1000-n.mi. range in crosswind sea clutter, σ_0 = -23 dB

```
                         RADIAL SPEED(KNOTS)

      -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5    99999999996           49999999999999994           69999999999
 6    99999999999981       1169999999999999611       18999999999999
 7    999999999999993       28999999999999982       399999999999999
 8    9999999999999994       499999999999994       4999999999999999
 9    99999999999999996     15999999999999951     69999999999999999
10    9999999999999999971    699999999999996    1799999999999999999
11    9999999999999999992    279999999999972    2999999999999999999
12    99999999999999999982   389999999999983   28999999999999999999
13    99999999999999999993    9999999999999    39999999999999999999
14    99999999999999999999   149999999999941   99999999999999999999
15    999999999999999999995  159999999999951  599999999999999999999
16    9999999999999999999961  6999999999996  1699999999999999999999
17    9999999999999999999991  6999999999996  1999999999999999999999
18    9999999999999999999997  3999999999993  7999999999999999999999
19    9999999999999999999997  3999999999993  7999999999999999999999
20    99999999999999999999982 4899999999984 28999999999999999999999
21    99999999999999999999993 1999999999991 39999999999999999999999
22    99999999999999999999993 1999999999991 39999999999999999999999
23    99999999999999999999999 2999999999992 99999999999999999999999
24    99999999999999999999999 2999999999992 99999999999999999999999
25    99999999999999999999999  69999999996  99999999999999999999999
26    999999999999999999999995 79999999997 599999999999999999999999
27    999999999999999999999996 79999999997 699999999999999999999999
28    9999999999999999999999961799999999997169999999999999999999999
29    9999999999999999999999961899999999998169999999999999999999999
30    9999999999999999999999991499999999994199999999999999999999999
```

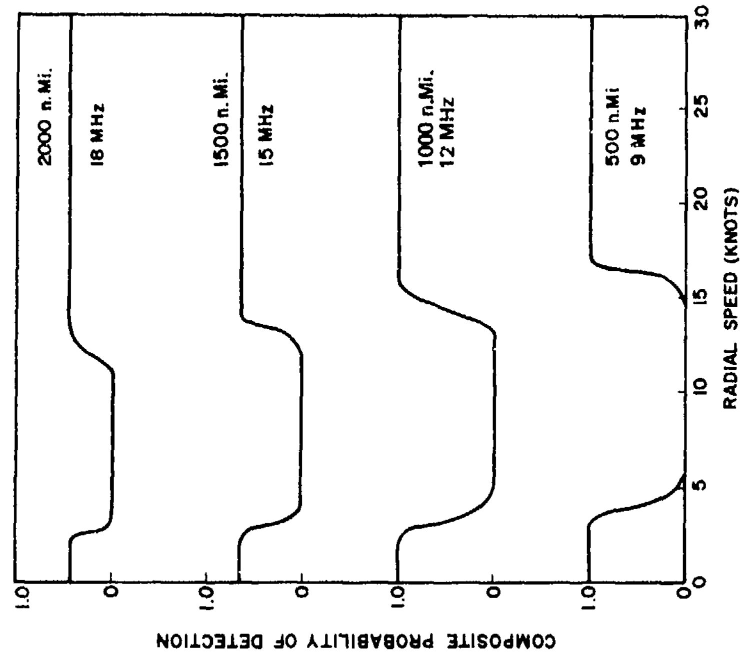
(S) Fig. 48—P_d of a 50,000-m^2 target at 1500-n.mi. range in crosswind sea clutter, σ_0 = -23 dB

```
                         RADIAL SPEED(KNOTS)

      -30  -25  -20  -15  -10   -5    0    5   10   15   20   25   30

 5    99999999993           27999999999999972           39999999999
 6    9999999999995          399999999999993          5999999999999
 7    999999999999971       15999999999999951       179999999999999
 8    9999999999999981       169999999999961       1899999999999999
 9    99999999999999992      289999999999982      29999999999999999
10    999999999999999994     399999999999993     499999999999999999
11    999999999999999999      4999999999994      999999999999999999
12    99999999999999999961   159999999999951   16999999999999999999
13    99999999999999999991    6999999999996    19999999999999999999
14    99999999999999999997    2999999999992    79999999999999999999
15    999999999999999999982   2999999999992   289999999999999999999
16    999999999999999999992   3899999999983   299999999999999999999
17    999999999999999999999   3999999999993   999999999999999999999
18    9999999999999999999994  1999999999991  4999999999999999999999
19    9999999999999999999994  1999999999991  4999999999999999999999
20    9999999999999999999995  1599999999951  5999999999999999999999
21    99999999999999999999991  69999999996  19999999999999999999999
22    99999999999999999999991  69999999996  19999999999999999999999
23    99999999999999999999996  79999999997  69999999999999999999999
24    99999999999999999999997  79999999997  79999999999999999999999
25    99999999999999999999997  39999999993  79999999999999999999999
26    999999999999999999999992 49999999994 299999999999999999999999
27    999999999999999999999993 49999999994 399999999999999999999999
28    999999999999999999999993 49999999994 399999999999999999999999
29    999999999999999999999993 59999999995 399999999999999999999999
30    999999999999999999999999 19999999991 999999999999999999999999
```

(S) Fig. 49—P_d of a 50,000-m^2 target at 2000-n.mi. range in crosswind sea clutter, σ_0 = -23 dB



(S) Fig. 50—Composite P_d of a 3000-m^2 target in crosswind sea clutter, $\sigma_0 = -17$ dB



(S) Fig. 51—Composite P_d of a 3000-m^2 target in crosswind sea clutter, $\sigma_0 = -23$ dB

below 13 knots if σ_0 = -23 dB. The composite P_d's are limited at long ranges by the probability of propagation. Thus, the composite P_d would be raised by any feature which improves propagation, such as allowing multiple-bounce propagation or increasing power.

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